CHAPTER 4
GEOPHYSICAL DETECTION EQUIPMENT

4-1. Introduction. This chapter presents an overview of available geophysical detection systems, their capabilities and limitations. There are many techniques beyond those mentioned in this chapter that have application to the detection of surface and subsurface UXO. No single detection system can effectively detect all types of munitions at all locations and depths.

4-2. Factors to Consider.

a. When selecting a geophysical survey instrument for detection of subsurface UXO, it is necessary to consider the maximum possible depth of UXO. If UXO is intentionally buried, factors affecting burial depth may include type of soil, mechanical vs. hand-excavation, depth of water table, etc. If the munition was fired or dropped, then the depth of penetration can be estimated by considering soil type, munition type and weight, and impact velocity. There are many cases where UXO can penetrate deeper than geophysical instruments can currently reliably detect. On such sites, it is possible that undetected UXO remains deeper than it can be detected.

b. Geophysical detection equipment used to locate subsurface UXO for avoidance or removal is seldom 100 percent effective. In many cases, a UXO may simply be located too deep, may be too small to be detected, or may be constructed of a material difficult to detect. Since the total number of subsurface UXO at a site is almost never known, complete detection cannot be documented. In addition, most commonly used geophysical survey systems will not detect subsurface bulk explosives. These factors must be considered when designing and implementing a UXO support response. If subsurface bulk explosives are anticipated based on archival data, then special avoidance techniques must be developed and increased safety precautions employed. Contact the OE MCX for additional information. The limitations of detection capabilities must be conveyed to all on-site personnel so that there is a common understanding of expectations.

4-3. Types of Instrumentation. The most successful UXO detection systems rely on one of two technologies: magnetometry or electromagnetics. Magnetometers are limited to detecting ferrous items. Electromagnetic detectors can detect any conductive metal.

a. Magnetometry.

(1) Magnetometers were one of the first tools used for locating buried munitions and remain one of the best. Most bombs and gun shells contain iron that causes a disturbance in the Earth's geomagnetic field. As the munitions are illuminated by the Earth's primary magnetic field, a secondary magnetic field results which magnetometers detect. Some magnetometers, which are called gradiometers, use two magnetic sensors configured to measure the slope (difference over a fixed distance) of the magnetic field, rather than the absolute magnetic field. Magnetometers are extremely sensitive and capable of identifying small anomalies. They

respond only to ferro-magnetic metals. In addition, magnetometers are sensitive to many iron-bearing minerals and "hot-rocks".

(2) Magnetometry will not detect subsurface bulk explosives. If subsurface bulk explosives are anticipated based on the site history, increased safety precautions and special techniques will be employed. Contact the OE MCX for additional information.

(3) Two types of magnetometers and gradiometers are most often used to detect buried munitions: fluxgate magnetometers and optically pumped atomic magnetometers.

(a) Fluxgate Magnetometers. Fluxgate magnetometers measure the magnitude and direction of a magnetic field. They are inexpensive, reliable, rugged, and have low energy consumption. Fluxgate magnetometers have long been a standard tool of EOD teams used for a quick, inexpensive field reconnaissance of a site containing ferrous munitions. However, most fluxgate magnetometers provide analog rather than digital output that makes it difficult to apply computer enhancement techniques.

(b) Optically Pumped Atomic Magnetometers. Optically pumped atomic magnetometers (also called atomic magnetometers or cesium-vapor magnetometers), also measure the magnitude and direction of a magnetic field. They utilize digital technology and are more expensive to purchase than fluxgate instruments. However, their high sensitivity, speed of operation, and high quality digital signal output make them a good choice for situations where data or digital post-processing is required.

b. Electromagnetic Detectors.

(1) Electromagnetic induction geophysical instruments are also extensively used to detect buried munitions. They differ from magnetometers in that they are not limited to detecting ferrous items; they can detect any conductive metal. In addition, electromagnetic detectors are not affected by most of the iron-bearing "hot rocks" that adversely affect magnetometers.

(2) There are numerous types of conductivity meters available. However, two types are most commonly used in the search for UXO: frequency-domain electromagnetics and time domain electromagnetic conductivity.

(a) Frequency Domain Electromagnetics. Frequency domain electromagnetic (FDEM) instruments can be useful for detecting large buried caches of munitions and detecting disturbed earth associated with pits and trenches. In addition, some types of FDEM instruments are the best geophysical tools available for detecting very small, very close objects such as the metal firing pins in plastic land mines buried just beneath the ground surface. However, since the resolution ability decreases dramatically with depth, frequency domain conductivity meters are not optimum for detecting individual, deeply buried munitions. Most commercial coin detectors are frequency domain conductivity meters.

(b) Time Domain Conductivity Electromagnetics. Time domain conductivity electromagnetic (TDEM) instruments provide an excellent compromise between detection depth and resolution. These instruments provide a capability to locate all types of metallic munitions and will see typical intact munitions to depths of one to two meters.

4-4. Geophysical Investigation Performance.

a. General. The performance of UXO detection instruments varies as a result of different site characteristics such as soil type, moisture content, depth to groundwater, vegetation, and type of UXO. The number of environmental and UXO factors affecting the performance of UXO detection instruments are so numerous that a test of various potential UXO detection instruments should be performed on the site to determine which instrument performs the best.

b. Performance Goals. Geophysical investigation performance goals will be included in the contractor's SOW. The most current contract requirements for geophysical investigation planning are found in the OE MCX Data Item Description "Geophysical Investigation Plan", which can be found on the OE MCX website at http://www.hnd.usace.army.mil/oew. If the contractor believes that these performance goals cannot be achieved at the site, then the contractor shall propose and document alternative goals for the Contracting Officer's consideration.

c. Horizontal Accuracy. Horizontally, 95 percent of all excavated items must lie within a 10 centimeter radius of their mapped surface location as marked in the field after reacquisition; 98 percent of all excavated items must lie within a 20 centimeter radius.

d. False Positives. There will be no more than 15 percent "false positives" where anomalies reacquired by the contractor result in no detectable, metallic material during excavations.

4-5. Test Plot. The Contracting Officer may require that the contractor demonstrate and document the capabilities of the proposed geophysical equipment. When the Contracting Officer requires a site-specific geophysical prove-out, a Work Plan that includes the test plot design will be prepared and implemented.

4-6. Calibration. Prior to use in the field each day, geophysical instrumentation will be checked for operational reliability and calibration against an item with a known response. Copies of instrument checkout and calibration verification will be maintained on-site. If calibration checks indicate that the instrument is not operating within an acceptable range and field adjustments do not resolve the discrepancy, the instrument will be immediately tagged and removed from service.

4-7. Maintenance. Preventative maintenance will be performed on a regularly scheduled basis. If an equipment problem is encountered, maintenance will be performed as soon as possible and records of the unscheduled maintenance and corrective action will be maintained and will indicate equipment identification, problem description, corrective action, the person performing the maintenance, and associated costs.